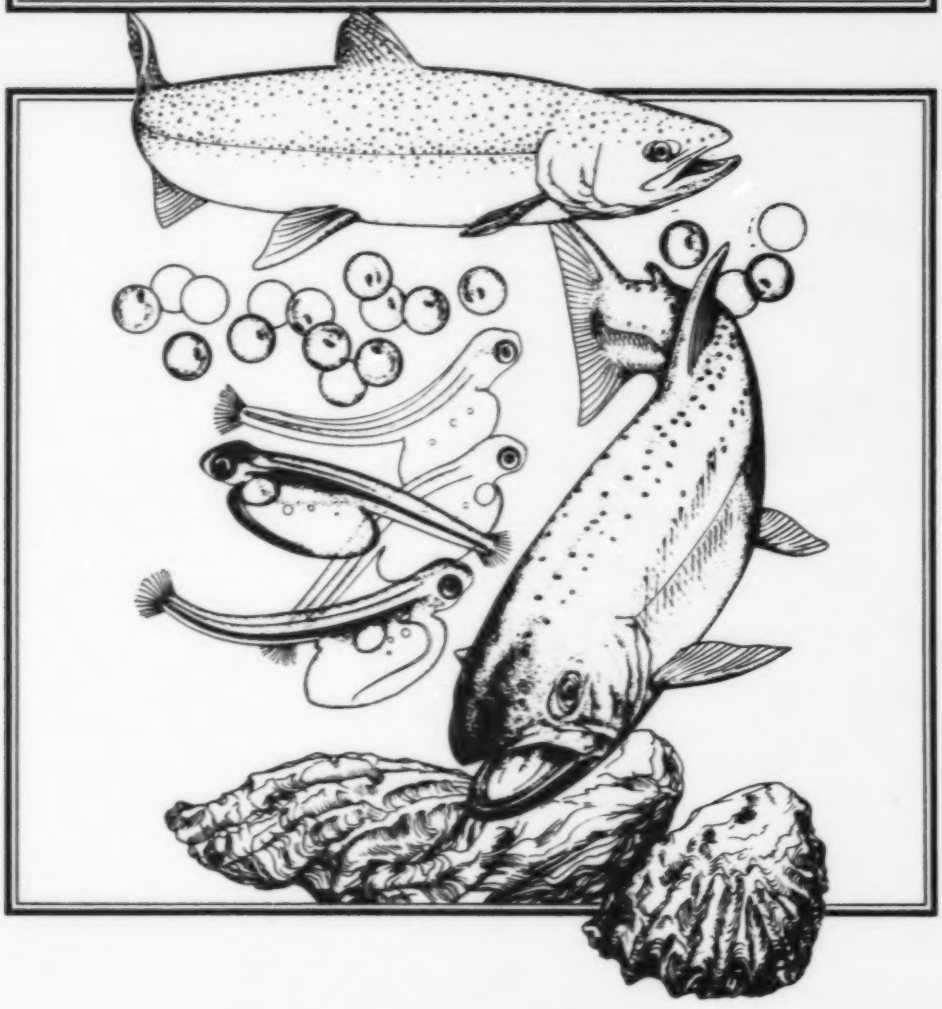
Aquaculture Industry Development Report

Commercial Freshwater Culture of Rainbow Trout in British Columbia



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Introduction

Aquaculture is a general term used to describe the propagation and rearing of aquatic organisms in controlled or semi-controlled environments. Commercial aquaculture operations generate profit by raising and selling product (fish or plants).

Interest in freshwater aquaculture has increased considerably over the last few years. The predominant species raised in British Columbia is rainbow trout, *Oncorhynchus mykiss*. Trout are commercially cultured for stocking-out, fee-fishing operations, and food market sales. Stocking-out includes rearing fish to supply other fish farms, private ponds, and operators of fee-fishing ponds.

Persons interested in pursuing commercial freshwater aquaculture are encouraged to read additional reference material (Appendix A) and contact the appropriate government agencies and industry groups (Appendix B). The prospective farmer should be aware of potential and existing problems that may arise unexpectedly when raising trout. Prior to starting an aquaculture operation the following factors should be carefully researched (Appendix C): farm and fish management, financing, site suitability, fish source, feeding and harvesting strategies, as well as the business and marketing aspects of the operation.

This booklet is intended as an introduction to fish culture only, and provides an overview of the technical, environmental, economic and legal aspects of commercial freshwater aquaculture in British Columbia. It is not a "how-to" explanation of fish culture.

The Ministry of Agriculture and Fisheries cannot be held liable for any failures in a fish culture venture, even after strict adherence to the following information.

Thanks are extended to staff of the provincial Ministry of Agriculture, Fisheries and Food who reviewed the document and provided the valuable advice that guided its development: Al Castledine, Linda Hall, Ed Black, Rob Armstrong and Joe Truscott.

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Industry Overview

The first license to commercially culture rainbow trout, *(Oncorhynchus mykiss)*, in British Columbia was issued in 1956. Since then, the number of commercial trout farms has increased from 2 to 173 in 1989. Most commercial freshwater operations are small and have developed as ancillary operations to agricultural farms or other business ventures.

The freshwater aquaculture industry has two main activities; the culture and sale of rainbow trout and the operation of fee-fishing ponds. Recently, the industry has shown increased activity and are exploring methods to increase the profile of the freshwater industry and to improve the profitability of existing operations.

In addition to rainbow trout, potential species for commercial freshwater culture in British Columbia include: Arctic charr *(Salvelinus alpinus)*, Atlantic salmon *(Salmo solar)*, *Oncorhynchus* sp., white sturgeon *(Acipenser transmontanus)*, and the signal crayfish *(Pacifastacus leniusculus)*.

Arctic charr appears to have good market and culture potential. Several B.C. trout growers are presently rearing charr for broodstock and food market sales. The production of Arctic charr will not increase substantially in the near future because eggs must be imported from a limited number of sources and the production technology is not well established. Charr offers a potential form of diversification for existing trout operations.

Between 1988 and 1989, 173 commercial fish culture permits were issued for rainbow trout. In addition to rainbow trout, five fish culture permits were issued for Arctic charr, seven for common carp, and two for crayfish.

Total 1988 sales for farmed B.C. trout were 117.5 tonnes (dressed weight). Sixty-five farms (38%) reported sales to the food or fee-fishing markets. The majority of 1988 growers (45%) are located in the lower Fraser Valley. This region supplies up to 76% of the total rainbow trout production (Figure 1.). The majority of B.C. trout is sold fresh as an 8-ounce, white-fleshed, dressed, head-on, gill-out product.

Freshwater aquaculturists are represented by three organizations (Appendix B): British Columbia Trout Farmers Association (BCTFA), the British Columbia Freshwater Aquaculture Cooperative (BCFAC), and the Kootenay Trout Growers Association (KTGA). BCTFA is the largest group with a province-wide membership, and is centralized in the lower Fraser Valley.

The Ministry of Agriculture and Fisheries is the lead agency for commercial aquaculture in British Columbia. The Aquaculture and Commercial Fisheries Branch issues and monitors commercial aquaculture licenses and provides technical assistance and information to both marine and freshwater aquaculturists.

Figure 1: Rainbow trout production in British Columbia, 1988 (Source: MAF). Three northern regions have a total of 5 farms reporting sales, the total annual production for these areas is up to 4 tonnes.

Total farms reporting sales = 59
Total dressed weight sold to food market = 117.5 tonnes

Introduction to Fish Culture

One of the first decisions to be made is what sort of operation you want: private fish pond for your own enjoyment or a commercial business. If the farm is to be a commercial venture the second task is to identify a target market for your fish:

i. **Food market:** The trout are reared to market-size (generally 8 to 10 ounces dressed) and sold fresh to the processor, retail market, restaurants, or direct to the consumer.

ii. **Stocking-out** (live fish or egg sales): Eggs are taken from broodstock and incubated, eyed eggs are shipped to other growers or incubated further to hatch. Fry are reared to fingerlings or larger, and sold to growers for stocking-out for further grow-out or fee-fishing.

iii. **Fee-fishing:** Customers fish from ponds stocked with catchable-sized fish and pay by the length or weight of the fish they catch.

A fish farm site must be suitable for growing fish and meet all regulatory requirements. The following section is intended to introduce the prospective fish farmer to fish culture. Good farm management is paramount to the success of a commercial aquaculture venture. The chosen site and facility design should enable efficient day-to-day activities, all-weather access, as well as provide emergency power back-up and area for expansion.

The Fish

Commercial aquaculture has focused on rainbow trout production for the following reasons:

- the culture technology and nutritional requirements are well established;
- domestic stocks are readily available;
- local water temperatures are suitable for trout culture;
- established market demand; and
- rainbow trout are native to British Columbia waters.

Domestic rainbow trout have been selectively bred for several generations to enhance commercially desirable characteristics such as; body shape and color, growth rate, spawning time, feed conversion, disease resistance, docility, and tolerance to crowding.

The fish farmer should be familiar with the basic anatomy of a fish (Figure 2 and 3).

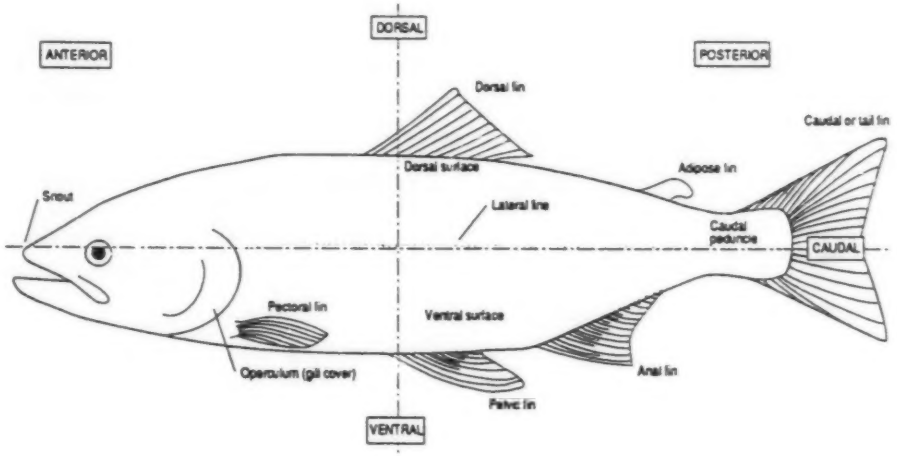


Figure 2: External profile of a fish, illustrating the orientation and terminology commonly used as descriptors (Source: Iwama, Intensive Fish Production, UBC Access, 1989).

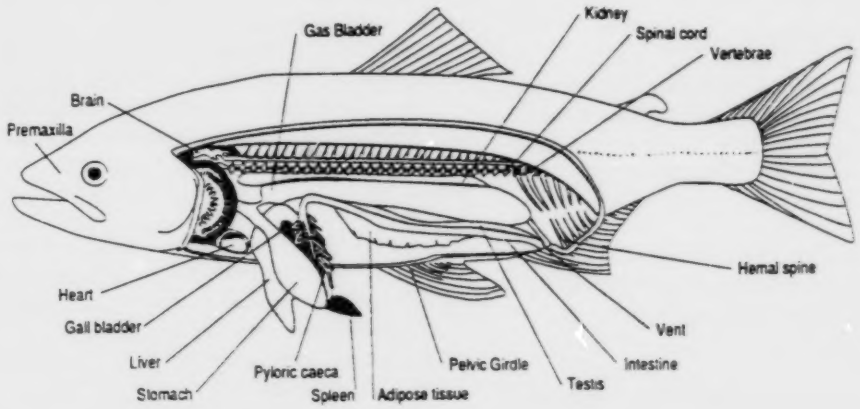


Figure 3: Internal anatomy of a male salmonid, the figure illustrates the internal organs and general skeletal plan (Source: Iwama, Intensive Fish Production, UBC Access, 1989).

Fish stock must be obtained from a licensed commercial fish farm. Most trout farmers purchase fry and fingerlings from local hatcheries. If the species is not available from a licensed facility, special approval must be obtained to remove "broodstock" from public waters (Ministry of Environment) or import disease-free eggs (Transplant Committee) (Appendix B).

Fish Growth

The rate of fish growth is dependent on a complex interplay of a variety of environmental and nutritional factors. The primary environmental factors are water temperature and the availability of dissolved oxygen. Fish growth rate can be predicted if the water temperature regime is known and fish are held under optimal growth conditions and fed a nutritious diet.

The expected growth of domestic rainbow trout fry over one year, at given temperatures, is provided in Table I. These values will vary between different trout stocks. Wild trout stocks will grow slower than domestic stocks.

Table I: The effect of temperature on the expected weight of trout fry over a given time period. The initial weight of the fry was 0.2 grams.

Temperature (oC)	Expected weight (gm) 3 months	6 months	9 months	12 months
10	4.7	20.8	56.2	118.4
11	5.6	26.0	71.7	152.4
12	6.7	32.2	89.8	192.5
13	7.9	39.2	110.7	239.0
14	9.3	47.2	134.7	292.5
15	10.8	56.2	161.9	353.4
16	12.5	66.2	192.5	422.2
17	14.3	77.4	226.8	499.4
18	16.3	89.8	264.9	585.5

Carrying Capacity

Carrying capacity is defined as the maximum number or weight of fish that a given environment can support for a given time. The carrying capacity of a rearing unit is influenced by the available tank volume and by factors such as; water quality, flow rate, fish size and fish species. A sufficient exchange of water through the system is required to maintain optimal dissolved oxygen levels and remove waste products.

There are two aspects to carrying capacity, the loading rate which is based on available flow (kg fish/ liter per minute) and density which is space related (kg fish per cubic meter). The calculation of carrying capacity is beyond the scope of this paper, however, Appendix C contains references that will assist its calculation. In order to make the most efficient use of a facility, the concept of carrying capacity must be well understood.

If water quality is questionable or the grower is inexperienced, initial tests should be conducted at half the calculated carrying capacity.

Fish Health

The commercial culturist's greatest asset is the fish and particular care must be taken to keep these animals living and growing.

Fish are subject to infection by numerous micro-organisms, including bacteria, viruses, and parasites, which can lead to disease. The crowded conditions of an artificial fish pond will stress fish, increasing susceptibility to these disease agents, therefore contributing to rapid spread of disease.

Fish husbandry measures that minimize stress are extremely important. For salmonids these include, but are not limited to, a good supply of high quality, well-aerated water, control of stocking densities, and minimal handling of the fish.

Two general methods to control disease are:

- Prophylactic treatment: a preventative measure administered prior to a disease outbreak; and
- Therapeutic treatment: an attempt to cure an existing problem.

Preventative disease control measures include:

- Stock ponds with healthy fish from a clean, well-run source.
- Minimize stress; over handled fish are more susceptible to disease.
- Maintain site cleanliness; ease of cleaning is an important consideration in facility design and all fish holding tanks and equipment must be cleaned regularly. Complete disinfection of a tank or raceway is essential following outbreak of a serious infectious disease.
- High quality diet; fish should receive a balanced and nutritious diet. Improperly fed fish have a much lower resistance to disease.
- Prophylactic immunization of young fish improves their resistance to specific disease problems to which they may be at risk.

Disease outbreaks will occur despite adherence to the most careful preventative measures, and the culturist should be alert to the earliest signs of a problem developing. Early recognition of sick fish is the initial step for successful therapeutant treatment. First indications of disease problems can be loss of appetite; abnormal distribution in the holding tank; flashing, scraping, or other erratic behavior; and/or general weakness and lethargy. Prompt action at the first sign of a problem will minimize fish loss.

The second step is a rapid, accurate diagnosis of the problem. Many common diseases can be recognized on-site by an experienced fish culturist or fish health technician. Professional veterinary advice will be necessary if medication is required to control the problem, or if the disease is complex and requires in-depth diagnostic work.

The farmer should consider the advantages and disadvantages to chemical treatment in consultation with the fish health veterinarian. Treatment may not be economically advisable if it results in increased stress to fish, or if drug withdrawal times will conflict with management plans to harvest.

Treatment methods available include:

- external applications (dip, prolonged bath, constant flow)
- systemic administration (addition to feed or injection)

Dosage calculations should be checked independently, initial testing of bath treatments on a small group is advisable, and lack of response to treatment should be investigated immediately.

Names and addresses of veterinarians in your area who are available for fish health consultations can be obtained from the B.C. Veterinary Medical Association Office (266-3441) or from the provincial Ministry of Agriculture and Fisheries fish health veterinarian (854-4400).

Fish Nutrition and Feeding

Trout raised by intensive aquaculture methods must be fed regularly. Under intensive culture systems, feed occurring naturally in the water will be insufficient.

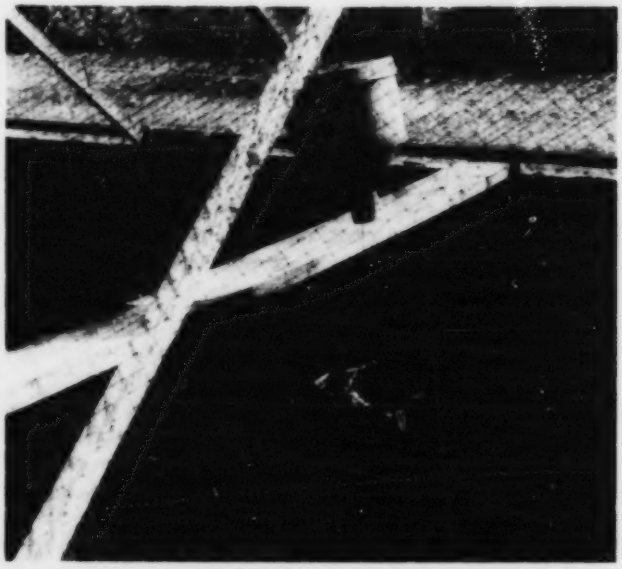
Many types of commercial fish feeds are available. Feed is described as pelleted or extruded and according to moisture level (ie. moist, semi-moist, semi-dry, dry). Feed performance is rated by the digestible energy content. Dry feed is easier to use, handle and store than moist feed. However, moist feed is generally easier to digest and more readily accepted by fish, particularly the fry and fingerlings. Feed is available in a variety of pellet sizes; the selection of a specific pellet size is dependent on fish size.

Feed can be distributed to the fish by hand or by automatic feeders. Automatic feeders are regulated by time switches or, in the case of demand feeders ("self-feeders"), by the fish.

Fish feed represent at least 40% of fish production costs. It is therefore, desirable to achieve the most efficient conversion of feed into flesh (ie. an efficient feed conversion rate (FCR))

$$\text{FCR} = \frac{\text{weight of feed consumed}}{\text{increase in fish weight}}$$

Trout farmers might expect a live weight gain of 1 kg for each 1.5 kg dry feed supplied (FCR=1.5). A low feed conversion rate generally results in a higher growth rate and less waste for economic production (Figure 4). The conversion of feed into fish becomes less efficient as the fish matures and grows.



Demand Feeder: as fish pull line, feed drops into pond.

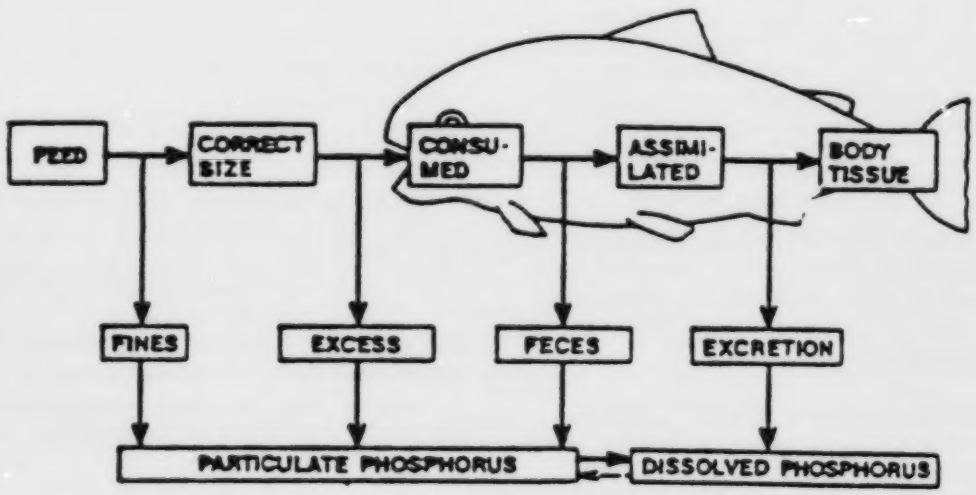


Figure 4: The fate of feed - assuming a feed conversion rate (FCR) of 1.5, 1.5 tonnes of feed are required to produce one tonne of fish.

The FCR should be carefully monitored by the aquaculturist to ensure that the fish are fed correctly and feed is not wasted. Incorrect feeding may stress the fish and result with water quality deterioration, poor fish growth and fish losses from disease, starvation, and cannibalism. Excess, wasted feed breaks down and degrades water quality by removing oxygen, and increasing suspended solids, ammonia, and phosphorus (see figure 4).

When developing a feeding strategy that will ensure the most efficient use of feed and the promotion of fish growth and health, keep the following suggestions in mind:

- explore the pros and cons of various feeding systems and select the appropriate system for the site;
- feed the fish routinely, in slow water flow systems (ie. pond) avoid feeding during the hot period of a day;
- ensure the fish receive all the feed and it is not dropped to the bottom or lost in the current;
- observe fish behavior during feeding, changes in behavior may provide an early warning to a developing problem;
- weigh a representative sample of fish at six-week intervals, calculate FCR and adjust feeding rate and feed size accordingly;
- hold fish off feed for at least 48 hours prior to handling or transporting;
- maintain individual pond records of FCR, % weight gain, water flow, dissolved oxygen in water, mortality, size and number of fish (Appendix E); and
- avoid overcrowding and low dissolved oxygen levels in water.

The amount of feed required by the fish depends on water temperature and fish size. Feeding rates change significantly as the fish grows; small fish require more feed (in terms of percent body weight), more frequently than do larger fish. The feeding rate for a given number of fish at a known temperature and body size is calculated as follows:

Feeding rate = total fish biomass x %BW/100

Where %BW is percent body weight derived from a feed table (Table II). Feed tables, advice on feeding methods, and nutritional information are available from feed distributors and manufacturers.

Mortality

An average annual mortality is generally near ten percent, however, it often ranges between zero to 100 percent. Fish death can result from a number of causes, many of which are linked with fish husbandry practices, water quality and facility cleanliness. Mortality rate will increase when fish are exposed to stress caused by factors such as; poor water quality; low oxygen levels; increased or rapid changes in temperature; over-crowded conditions; and excessive or rough handling.

Table II: Recommended feeding table for rainbow trout
(Source: Rangen Feeds).

Recommended Feed Size	Fish Count per Pound	Fish Weight in Grams	Fish Length in Inches	Water Temperature °F / °C	41 / 5	44 / 6.7	47 / 8.3	50 / 10	53 / 11.7	56 / 13.3	59 / 15	62 / 16.7
				Feeding Rate as a Percentage of Body Weight*								
TROUT & SALMON STARTER												
#1	1200-600	.4-.8	1-1½		3.5	4.0	4.5	5.2	6.0	6.8	7.8	8.9
#2	600-300	.8-1.5	1½-2		2.9	3.3	3.8	4.4	5.0	5.7	6.6	7.5
#2	300-200	1.5-2.3	2-2¼		2.5	2.8	3.2	3.7	4.2	4.8	5.5	6.3
#3	200-100	2.3-4.5	2¼-2½		2.2	2.5	2.9	3.3	3.8	4.4	5.0	5.7
#3	100-80	4.5-6	2½-3		1.9	2.1	2.4	2.8	3.2	3.7	4.2	4.8
TROUT GROWER												
#4	80-60	6-8	3-3¼		1.9	2.1	2.5	2.8	3.2	3.7	4.2	4.8
#4	60-40	8-11	3¼-4		1.7	2.0	2.3	2.6	3.0	3.4	3.9	4.5
#4	40-30	11-15	4-4½		1.6	1.8	2.1	2.4	2.7	3.1	3.5	4.0
CC.3/32"	30-20	15-23	4½-5		1.5	1.7	1.9	2.2	2.5	2.9	3.3	3.8
CC.3/32",1/8"	20-15	23-30	5-5½		1.3	1.5	1.7	2.0	2.3	2.6	3.0	3.4
3/32",1/8"	15-12	30-38	5½-6		1.2	1.4	1.6	1.8	2.1	2.4	2.8	3.2
1/8",5/32"	12-9	38-50	6-6½		1.2	1.3	1.5	1.7	2.0	2.3	2.6	3.0
TROUT PRODUCTION												
5/32"	9-6	50-76	6½-7¼		1.1	1.3	1.5	1.7	2.0	2.2	2.6	2.9
5/32"	6-4	76-114	7¼-8		1.0	1.2	1.4	1.5	1.8	2.0	2.3	2.7
5/32"	4-3	114-151	8-9½		.9	1.1	1.2	1.4	1.6	1.8	2.1	2.4
5/32"	3-2	151-227	9½-11		.9	1.0	1.1	1.3	1.5	1.7	1.9	2.2
5/32"	2-1	227-454	11-13		.8	.9	1.0	1.2	1.3	1.5	1.8	2.0
3/16"	1-.5	454-908			.7	.8	.9	1.0	1.1	1.3	1.5	1.7
1/4"	> .5	> 908			.6	.6	.7	.8	1.0	1.1	1.2	1.4

Estimated feed required in each size for 10,000 fish:

Rangen feed size	Count per pound	Expected conversion*	Estimated feed required
Swimup	4000-2000	.75	2 lbs.
No. 1	2000-900	.80	5 lbs.
No. 2	900-225	.85	28 lbs.
No. 3	225-90	1.0	67 lbs.
No. 4	90-35	1.18	207 lbs.
Coarse Crumble	35-12	1.24	678 lbs.
1/8" & 5/32" Pellet	12-2	1.32	5,500 lbs.
5/32" Pellet	2-1	1.38	6,900 lbs.
Total		1.34	13,397 lbs.

The introduction of toxic materials into trout-rearing waters may cause excessive mortality. Pesticides and fertilizers often contain chemicals toxic to fish, even when in very small concentrations. In addition, if fish metabolic wastes and waste feed are allowed to accumulate within rearing tanks "self-pollution" may occur (refer to Figure 4).

The following suggestions may help to reduce the mortality rate:

- be familiar with activities and conditions that may distress the fish, avoid or minimize exposure to potential stressors;
- ensure high dissolved oxygen levels by removing pond vegetation regularly, providing sufficient water flow and aerating if necessary;
- where possible maintain optimal water temperature and avoid exposing the fish to rapid changes in temperature;
- clean facilities periodically and disinfect equipment;
- immunize or purchase immunized fish stock;
- feed correctly and provide a nutritious diet;
- control stocking densities and avoid over crowding
- exclude predators from the pond (e.g. use an enclosed shed or netting)
- avoid using pesticides/fertilizers near rearing facilities or water sources; and
- know the fish and be aware of problems that may arise.

In summary, rainbow trout require a supply of clean, cool water with relatively high dissolved oxygen concentrations. The fish must be kept under regular supervision; they must be fed and monitored for disease. The farmer should know the fish and potential problems, as well as understand and use fish husbandry and farm management methods. A commercial farm requires a considerable commitment to succeed and the grower's lifestyle must be adapted to it.

Production Cycle and Fish Husbandry Practices

The trout farmer should be familiar with the various growth stages within the production cycle and the timing of each stage (Figure 5).

Terminology:

1. **Green eggs:** A stage in egg development from the time of fertilization to "eyeing up".
2. **Eyed eggs:** The embryo stage at which pigmentation of the eyes becomes clearly visible through the egg shell.
3. **Sac-fry:** Newly hatched fry where the external yolk sac has not yet been absorbed. Also referred to as "alevins".
4. **Fry:** The stage in a fish's life from the time it hatches until it reaches a length of 1 inch.
5. **Fingerlings:** The stage in a fish's life from a length of 1 inch to approximately 6 inches.
6. **Market-size:** Fish suitable for market sale, generally 9 to 10 inch fish weighing 8 to 12 ounces.
7. **Broodstock:** Mature fish retained for spawning.

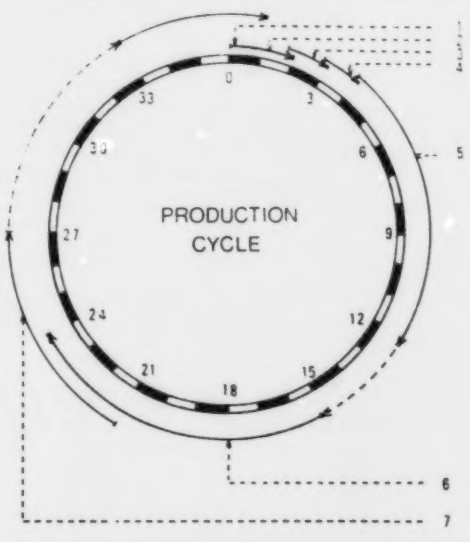


Figure 5. Model of production cycle for rainbow trout held in 10oC water; inner numbers represent time in months (Source: Aquaculture in Ontario).

Broodstock

Rainbow trout females can be stripped (ie. eggs and milt removed) at two, but more commonly at three years old. Stripped broodstock may be replaced in ponds and used again in their fourth and fifth year. To reduce the likelihood of detrimental inbreeding, new broodstock are brought into the breeding population periodically.

When the fish is "ripe" (ie. eggs are loose in body cavity and ready to be shed), it is usually anesthetized and hand stripped into a dry container. Milt from the male fish is gently mixed with the eggs. Water is then added, which serves to "water-harden" the fertilized eggs.

Egg Incubation

Following fertilization the eggs are transferred to egg incubators. From 48 to 72 hours after fertilization the eggs are very susceptible to damage and must not be handled or moved. At this fragile stage the eggs are referred to as "green eggs". Following a specific time for incubation two black dots can be seen through the egg shell; eggs at this stage are described as "eyed". Eyed eggs are less susceptible to damage and can be handled and transported.

The timing of various stages of development, such as time of eye-up and hatch, can be estimated by calculating the accumulated temperature units (ATU's). ATU = the sum of daily temperatures (oC) for a given period. Rainbow trout eggs held at 10oC should eye-up at approximately 170 ATU (or in 17 days), and 50% hatch should occur near 330 ATU's (or 33 days).

Numerous systems have been designed for incubating salmonid fish eggs. Hatchery tray systems are most common, particularly in cases where large numbers of eggs are incubated, however sac-fry (alevins) must be transferred to troughs soon after hatch. Hatchery boxes are most suitable for farms specializing in both egg and fry production. Alevins are able to remain within the box until swim-up.

Hatchery design should provide adequate water flows and ensure that silt can not enter the system and that the eggs are not exposed to direct light or to movement.

Early Rearing

Following hatch, the alevins are transferred to early rearing troughs. When the fry begin swimming-up from the bottom of the tank (swim-up fry, 2.5 cm) they begin to feed on commercial trout starter diet. In general, the mortality rate from hatch to 6 cm-fry is less than 15%. In most cases, 8 to 10 cm-fry are graded for size and transferred to tanks/ponds designed for grow-out.

Grow-Out

Maximum stocking density is dependent in part on available flow rate, pond design and construction. For example, stocking density should not exceed 12 kg/m3 in earthen ponds and 35 kg/m3 in concrete raceways.

On average, the trout farmer can plan to produce 4 kg trout per liter/min. Risks of fish loss increase under higher density conditions and additional measures must be taken to maintain adequate water quality. An experienced trout farmer may reach an annual production of 10 kg trout for every liter/minute water flow.

Rearing Facilities

Several types of rearing facilities are available to the trout farmer depending on the type of activity: holding broodstock; incubating eggs and early-rearing (hatchery); or rearing fish to market size (grow-out). Generally, rearing facilities are designed to provide the following:

- uniform water flow;
- screened inflow to prevent debris and wild fish from entering the system;
- easily drained for removing fish and cleaning;
- minimum of water seepage;
- access around pond for operations and maintenance;
- predator control; and
- protection from freezing.

Hatchery

The hatchery is designed to incubate and hatch eggs, and to rear fry to the fingerling stage. A variety of egg incubating systems are available, ranging from hatchery tray systems, hatchery baskets (or boxes), to upwelling incubators.

Early rearing troughs are usually constructed of concrete or Fiberglas. Typical trough dimensions are 3 or 4 meters long, 0.7 to 0.8 meters wide and 0.5 to 0.6 m deep. Often early rearing troughs are also used for egg incubation by placing hatchery baskets within the trough (Figure 6).

Relatively low water flows are required to incubate eggs and rear fry. Due to these low flows, it is often cost-effective to raise the water temperature to accelerate egg development and early fish growth.

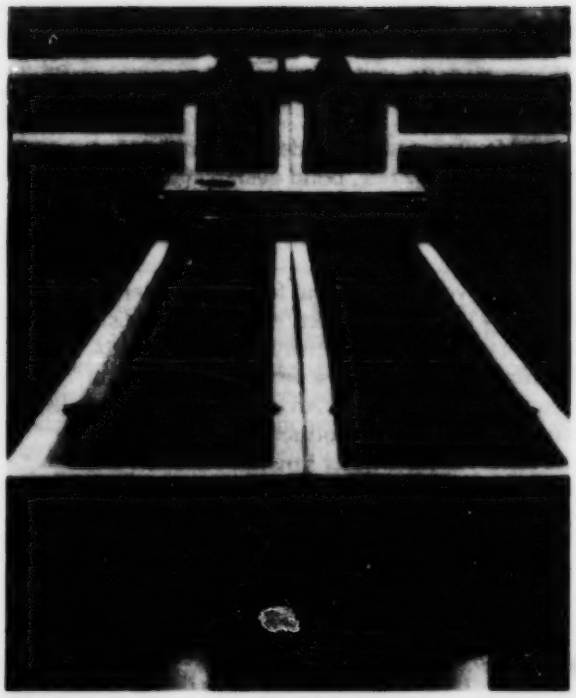


Figure 6: Early rearing trough with automatic feeder.

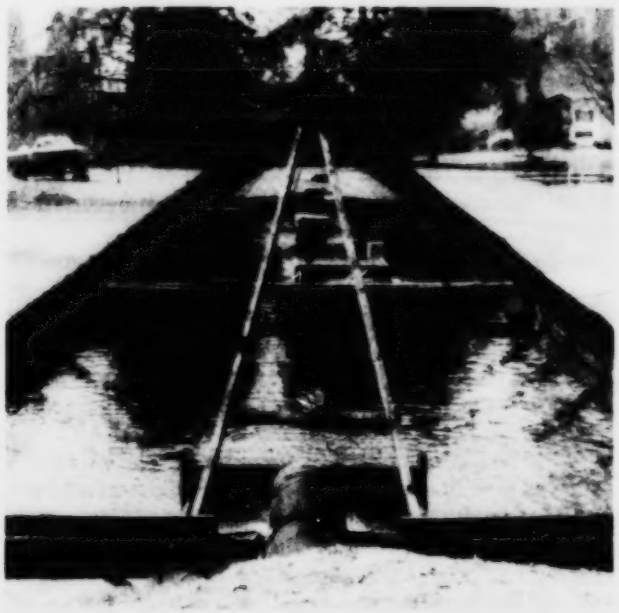
Grow-out Structure: Pond Design

Rearing ponds or tanks are used to raise fish to yearling size or larger. Rearing ponds should be designed to enable good water exchange, rapid cleaning (preferably "self-cleaning"), complete drainage and disinfection, as well as easy access to fish stock for handling and harvest.

To best meet these, and other specific needs, the aquaculturist may select from a variety of pond designs, such as; natural and excavated earthen ponds, long raceways, and circular tanks. The tanks/ponds may be set in or above ground; be plastic-lined; and/or built of earth, cement, metal, Fiberglas, or wood. As the diversity in pond design precludes a lengthy discussion here, the prospective aquaculturist should refer to Appendix C for more detailed reading.

Natural Ponds: Natural ponds may be used for rearing fish, but are not generally suitable for commercial-scale production. Disadvantages may include low production capability, fluctuations in water temperature, inadequate flushing allowing sediment accumulation and an increased potential for disease, difficulty in harvesting due to size of pond and configuration, the lack of uniformity in size of fish produced, aquatic vegetation, and the potential for winter-kill.

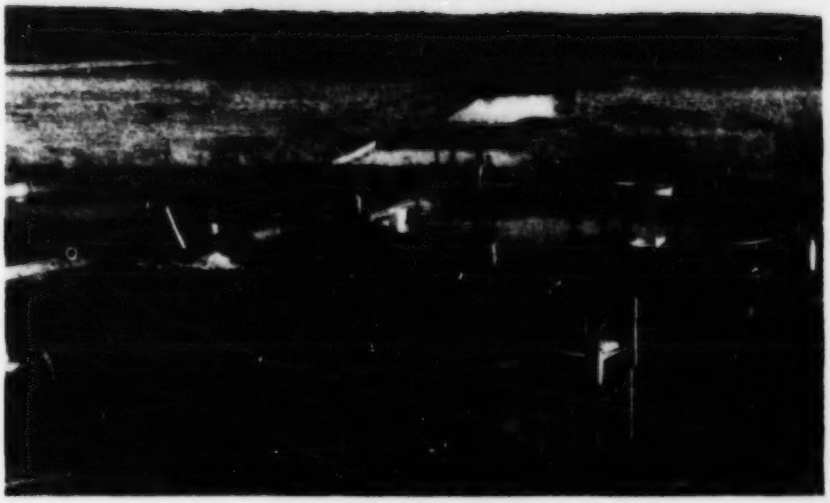
Earthen Ponds: Earthen ponds are used successfully in many commercial operations. These ponds are typically 25 meters long, 12 meters wide with an average depth of 1.5 meters. Earthen ponds are inexpensive and easy to construct but are generally more difficult to manage than other artificial structures. As a result, production capacity is lower than in raceways and disease as well as inventory control is more difficult.



Earthen Pond

Raceways: Concrete raceways are typical of present commercial trout culture practices. Dimensions vary, but are generally 15 to 25 meters long, 2 to 3 meters wide, and 0.5 to 1.0 meter deep. Raceways may be set up in series with several units using the same water. Raceway design allows the farmer to hold several separate groups of fish in one unit by the use of screens, and to easily access fish for grading, disease treatment and harvesting. The water level can be easily manipulated and fish efficiently removed from the units. A disadvantage of raceways is that the fish tend to congregate at the inflow where incoming water provides maximum oxygen levels and current. As a result the total volume of the raceway is not fully utilized.

Circular Tanks: Circular tanks range from 2 to 7 meters in diameter and 0.5-0.8 meters in depth, sloping to a central drain (Figure 7). Water is introduced in a manner that sets up a counterclockwise circular flow producing a self-cleaning effect as waste material collects at the central drain. The fish tend to distribute themselves evenly throughout the tank utilizing rearing space more effectively than in other systems. Fin condition of fish reared in circulars is often better than that of fish raised in raceways. The disadvantages of circular tanks include: difficulty handling larger fish and as a result of the flow pattern within the tank, localized areas of poorer quality water can develop.



Circular tanks with earthen pond in background.

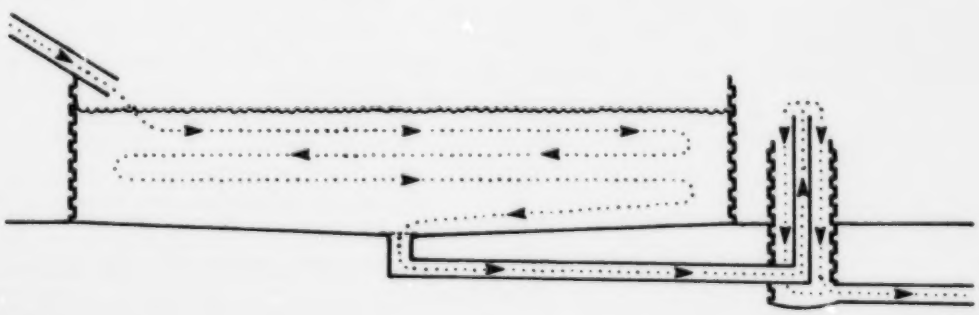


Figure 7: Diagram of a circular tank showing the water flow pattern and the control of water level using a standpipe of different heights. (Source: Aquaculture in Ontario, Ontario Min. of Natural Resources, 1988).

Water Supply

Water quality and quantity are critical factors that will ultimately determine the selection of an aquaculture site. Desirable characteristics of a water supply include:

- relatively constant water flow and temperature;
- high levels of dissolved oxygen (D.O.);
- low levels of silt and harmful gases;
- no chemical or organic pollution; and
- no resident populations of wild fish.

Water Source

Freshwater may originate from either a ground (artesian springs, wells) or surface (streams, lakes etc.) water source. Ground water sources are generally preferable for fish culture. Their stable water temperature, chemistry and flow rate, low silt load, and relatively pathogen and pollution-free water help to minimize stress for the fish and thus promote fish health. Unfortunately, ground water is often low in dissolved oxygen and high in nitrogen gas, however these conditions can be overcome inexpensively by directing the water over an aeration tower.

Surface water is not as desirable as ground water, however it maybe suitable for production purposes. The disadvantages of surface water include fluctuations in temperature and flow rate, and possible contamination by pollution and/or pathogens. Low winter temperatures result in slow fish growth and high summer temperatures will stress the fish. Distressed fish tend to be more susceptible to disease.

Water Quality Parameters

A consistent supply of high quality water is required for trout culture. Water quality criteria for salmonid culture are identified in Table III. These criteria serve as general guidelines only, but will help to identify potential problems.

Water for use by a proposed fish farm or hatchery should first be checked by chemical analysis. Testing kits are available from scientific supply companies, or you may wish to hire a consultant to carry out water quality tests. In some cases, the prospective farmer may wish to conduct a simple trial by rearing small batches of fish in the water and monitoring survival.

Fish production capacity is limited by the quantity and quality of water available. Flow rates must be sufficient to remove metabolic wastes and maintain oxygen levels, but not so great that the fish must swim too vigorously. Water quality parameters are affected by fish metabolism and the accumulation of waste products (Table IV); these affects can be predicted. The requirements for water flow rate depend on a number of factors, including fish biomass, and the temperature and quality of the water source.

Table III: Water quality standards for salmonid culture*

(> = greater than; < = less than)

Alkalinity(total as CaCO3)		120 - 400**
Ammonia: total	<	2.0
unionized (NH3)	<	0.013**
Cadmium: hard water	<	0.003
soft water	<	0.0004
Calcium		5 - 160
Carbon dioxide	<	2.0
Chlorine	<	0.003
Chromium	<	0.03
Copper: hard water	<	0.03
soft water	<	0.006
Dissolved oxygen (measured at outlet)	>	6
Dissolved gas pressure (total)	>	103% saturation**
Hardness (total as CaCO3)		10 - 500
Hydrogen sulfide	<	0.002
Iron (total)	<	0.15
Lead	<	0.03
Magnesium	>	20
Manganese	<	.01
Mercury	<	0.0002
Nickel	<	0.02
Nitrate-nitrogen	<	10
Nitrite-nitrogen	<	0.05
Ozone	<	0.005
pH		6.5 - 8.0
Phosphorus: total		0.01 - 3.0
soluble	<	1.0
Solids: total dissolved	<	800
suspended/settlable	<	80
Sulfate	<	500
Temperature		10-15.5 oC**
Turbidity	<	2,000
Zinc	<	0.05

(Source: * OAC Publication 0989; **Piper et al. 1982)

Values in mg/l unless otherwise stated (mg/l = ppm)

Table IV: Effect of fish rearing on selected water quality parameters

Parameter	Value at Inflow	Effect of Fish Rearing
Dissolved oxygen	100% saturation	decreased by fish metabolism and decomposition of organics
Ammonia (total)	< 2.0 ppm	increased, product of fish excretion and decomposition of organics
(toxic NH3)	< 0.013	increased due to a pH increase caused by fish metabolism
Nitrite & Hydrogen sulfide	not detectable	increased by decomposition of organics
Suspended/settlable solids	< 80 ppm	increased by feces and waste feed

Temperature, dissolved oxygen (D.O.) and ammonia are the most significant parameters in intensive fish culture operations:

Temperature

Fish are ectothermic, that is their body temperature fluctuates with the temperature of their environment. Each species has a preferred temperature range. Rainbow trout can survive at temperatures ranging from 1 - 25 oC, but the optimum is 10 to 15 oC. The water temperature should be as close to the optimum range as possible to ensure the fastest growth and most efficient conversion of fish food to fish weight (refer to Table I).

Temperatures below the optimal level result in slower growth and increase the time required to raise the fish to market size. Consequently, low rearing temperatures will raise production costs.

Temperatures above 18oC will distress the fish, which may result in a reduced growth rate and increased susceptibility to disease; temperatures above 24oC are often lethal. The problem is enhanced if the fish are over-crowded, improperly fed, or handled. Changes in temperature should always be gradual, rapid temperature changes are stressful and may cause direct mortality or predispose the fish to disease.

Dissolved Oxygen (D.O.)

Trout require well-aerated water. The ability of water to hold oxygen is affected by the elevation of the water source and the water temperature. As elevation and temperature increase, the dissolved oxygen level in the incoming water decreases (Table V and Figure 8).

The requirement for oxygen by fish is affected by water temperature, species of fish cultured, their physical activity, fish size, and the availability of feed. As water temperature increases, its ability to hold oxygen decreases. Concurrently, the higher temperatures increase the metabolic rate of the fish, which results in an increased requirement for oxygen (Figure 8). The demand for oxygen by the fish will also increase as physical activity is increased and as feed is consumed and digested.

To maintain good fish growth and survival, D.O. must be monitored on a regular basis; D.O., when measured as the water flows from the system, should not fall below 6 mg/l (mg/l = ppm). If D.O. is found to be suboptimal it may be necessary to adjust fish densities, water flow rates, the feeding regime, and/or aerate the water accordingly. Keep in mind that a reduction in D.O. occurs soon after feeding: avoid feeding the fish when the D.O. is at a critical level.

When determining the loading rate for a rearing tank it is advisable to base calculations on the warmest water temperature and slowest flow rate that will be experienced at the site.

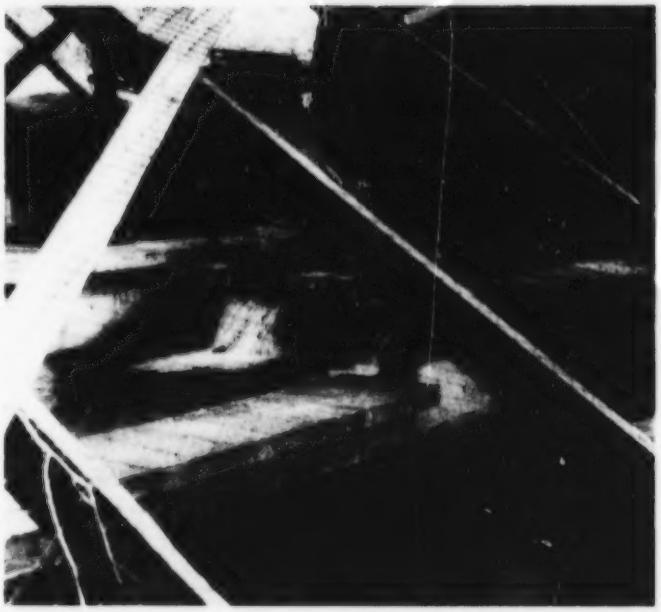
The D.O. in a pond can be improved by:

1. Removing organic waste and plants on a regular basis.

Decaying organic material removes oxygen from the water, therefore all organic waste (feces, excess feed, mortalities, leaves etc.) should be removed from rearing tanks. To reduce the effects of oxygen depletion by microbial activity and to maintain a clean system, rearing tanks should be designed to be "self-cleaning".

2. Recharging oxygen levels.

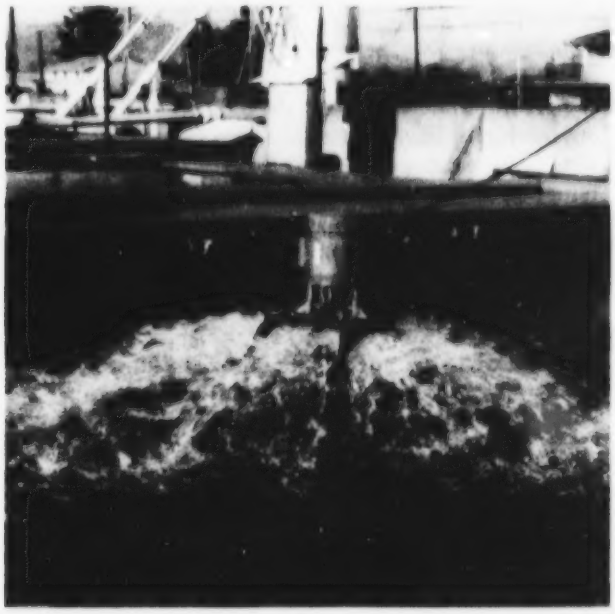
The D.O. level can be increased by: building a fall (of about 0.9 meters) between raceways in series, surface aerators, or oxygen injection systems. A weir (shown below) built between successive raceways increases the waters exposure to air, therefore raising its oxygen content. The weir also enables the farmer to control water levels and measure volume of water flow (see Appendix D).



Recharging oxygen levels with a "fall" between raceways.

3. Increase oxygen level at water inflow using aeration towers.

Aeration tower at water inflow.



Surface Aerators

4. Ensure sufficient water flow, adequate pond depths and wind exposure.

Table V: Dissolved oxygen in parts per million (or mg/l) for freshwater at 100% saturation (Source: J. Colt, Dept. of Civil Engineering, UC Davis).

Water Temp	Elevation (meters)									
(C)	0	200	300	500	600	700	900	1000	1200	1500
0	14.60	14.34	14.09	13.84	13.59	13.35	13.11	12.88	12.65	12.43
1	14.20	13.95	13.70	13.46	13.22	12.98	12.75	12.53	12.30	12.08
2	13.81	13.57	13.33	13.09	12.86	12.63	12.41	12.19	11.97	11.76
3	13.45	13.21	12.97	12.74	12.52	12.29	12.07	11.86	11.65	11.44
4	13.09	12.86	12.63	12.41	12.19	11.97	11.76	11.55	11.34	11.14
5	12.76	12.53	12.31	12.09	11.87	11.66	11.46	11.25	11.05	10.85
6	12.44	12.21	12.00	11.78	11.57	11.37	11.17	10.97	10.77	10.58
7	12.13	11.91	11.70	11.49	11.29	11.09	10.89	10.69	10.50	10.32
8	11.83	11.62	11.41	11.21	11.01	10.81	10.62	10.43	10.25	10.06
9	11.55	11.34	11.14	10.94	10.75	10.55	10.37	10.18	10.00	9.82
10	11.28	11.08	10.88	10.68	10.49	10.31	10.12	9.94	9.76	9.59
11	11.02	10.82	10.63	10.44	10.25	10.07	9.89	8.71	9.54	9.37
12	10.77	10.57	10.38	10.20	10.02	9.84	9.66	9.49	9.32	9.15
13	10.53	10.34	10.15	9.97	9.79	9.62	9.44	9.27	9.11	8.95
14	10.29	10.11	9.93	9.75	9.58	9.40	9.24	9.07	8.91	8.75
15	10.07	9.89	9.71	9.54	9.37	9.20	9.02	8.87	8.71	8.56
16	9.86	9.68	9.51	9.34	9.17	9.00	8.84	8.68	8.53	8.37
17	9.65	9.48	9.31	9.14	9.98	8.81	8.66	8.50	8.35	8.20
18	9.45	9.28	9.12	8.95	8.79	8.63	8.48	8.32	8.17	8.03
19	9.26	9.09	8.93	8.77	8.61	8.46	8.30	8.15	8.01	7.86
20	9.08	8.91	8.75	8.59	8.44	8.29	8.14	7.99	7.84	7.70
21	8.90	8.74	8.58	8.42	8.27	8.12	7.98	7.83	7.69	7.55
22	8.73	8.57	8.41	8.26	8.11	7.96	7.82.	7.68	7.54	7.40
23	8.56	8.40	8.25	8.10	7.96	7.81	7.67	7.53	7.39	7.26
24	8.40	8.25	8.10	7.95	7.81	7.66	7.52	7.39	7.25	7.12
25	8.24	8.09	7.95	7.80	7.6	7.52	7.38	7.25	7.12	6.99
26	8.09	7.95	7.80	7.66	7.52	7.38	7.25	7.11	6.98	6.86
27	7.95	7.80	7.66	7.52	7.38	7.25	7.11	6.98	6.86	6.73
28	7.81	7.66	7.52	7.39	7.25	7.12	6.99	6.86	6.73	6.61
29	7.67	7.53	7.39	7.26	7.12	6.99	6.86	6.74	6.61	6.49
30	7.54	7.40	7.26	7.13	7.00	6.87	6.74	6.62	6.50	6.38

Assumptions:

Pressure at sea level is 760.0 mm
Salinity = 0.0 ppt
Mean air temperature is 20 oC

Example:

E = 200 meters and T = 20 oC, then DO = 8.91 mg/L

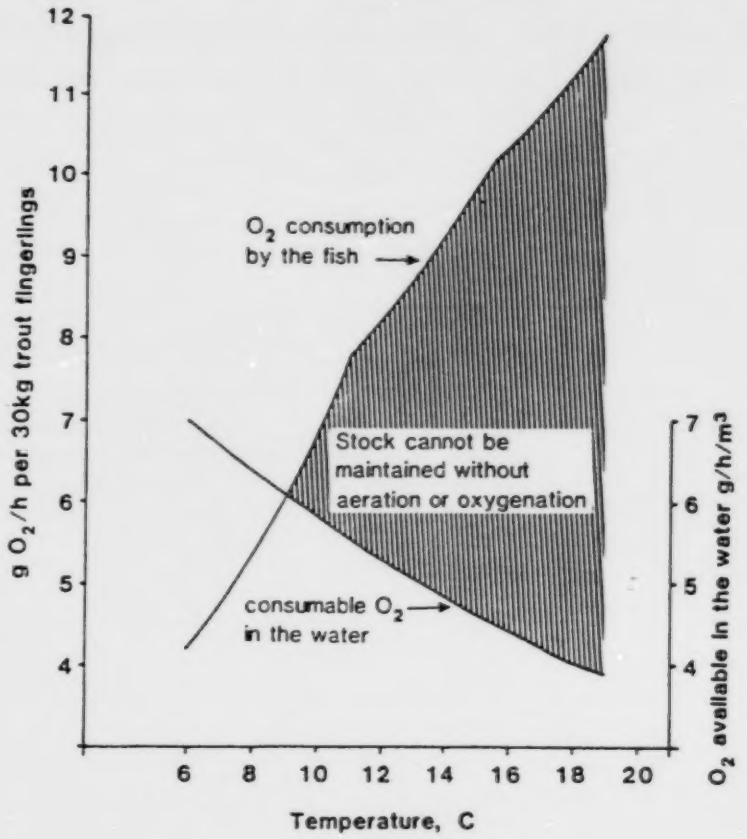


Figure 8: The effect of temperature on oxygen demand by fish compared with oxygen in the water supply. The scale on the right shows how the oxygen level in the water supply declines with increasing temperature. The scale on the left shows the consumption of oxygen by 30 kg of 125-gram trout in a tank. Note the rapid increase in oxygen demand with temperature. Unless water flow is increased, supplemental aeration is necessary to ensure fish survival above 9 oC. (Source: J. Colt, Dept. of Civil Engineering, UC Davis).

Ammonia

Ammonia may be found in surface water contaminated by agricultural run-off, and may occur naturally in ground and surface waters resulting from the microbial breakdown of material containing nitrogen. Ammonia is also the primary form of nitrogen excretion by many fish species.

Ammonia is present within the water in one of two forms: ammonium ions (NH4+) and unionized ammonia (NH3). Unionized ammonia is highly toxic to fish.

Ammonia is measured as "total ammonia" (NH3 plus NH4+). The relative proportions of each form varies with the pH and temperature of the water. As pH increases, the proportion of toxic unionized ammonia increases. The percent of total ammonia that is NH3 (toxic) has been calculated for a range of pH and temperatures (Table VI). Using Table VI, and knowing the pH, temperature, and total ammonia content of the water, the amount of unionized ammonia (ppm = mg/l) can be calculated as follows:

Example: water temperature = 10oC
water pH = 7.0
total ammonia = 10.5 ppm

Therefore:
Unionized ammonia (ppm) = [total ammonia (10.5 ppm) x unionized ammonia (0.19% - taken from table VI)]/100
= 0.020 ppm NH3, which is higher than the maximum concentration of NH3 recommended in Table III.

Table VI: Percent of total dissolved ammonia (NH3 plus NH4+) which is unionized (toxic - NH3) as a function of pH and water temperature (Trussel, 1972).

pH	Water Temperature				
oC	5	10	15	20	25
6.5	.04	.06	.09	.13	.18
6.7	.06	.09	.14	.20	.28
7.0	.12	.19	.27	.40	.55
7.3	.25	.37	.54	.79	1.10
7.5	.39	.59	.85	1.25	1.73
7.7	.62	.92	1.35	1.96	2.72
8.0	1.22	1.82	2.65	3.83	5.28
8.3	2.41	3.58	5.16	7.36	10.00
8.5	3.77	5.55	7.98	11.18	14.97
8.7	5.85	8.53	12.02	16.63	21.82
9.0	11.02	15.68	21.42	28.47	35.76

Other Water Quality Parameters

Detectable concentrations of the following may reduce water quality sufficiently to render it unsuitable for rearing trout:

- residual chlorine
- phenolics
- cyanide
- sulfide
- surfactants
- pesticides
- oils

The Business of Trout Farming

Market

The critical and first step in exploring the prospects of a new business is to examine the market. Markets for aquaculture products are limited and it takes a great deal of ingenuity to develop and maintain them. Production of trout may be difficult but selling at a price that generates acceptable profit may prove much more difficult, if the initial footwork has not been carried out.

Production

Raising trout is time-consuming and risky, the farmer must be committed to the project, and be aware of potential problems that may arise. A disease outbreak or power failure, resulting in loss of water flow, may result in excessive fish mortality and therefore, a loss in revenue. To help reduce the potential for these losses back-up systems should be incorporated into the facility design. Long hours are required for the farm's routine operation: feeding fish, regular disease and water quality monitoring, cleaning the facilities, record-keeping, managing the business, etc.

The farmer should ensure that the farm is working at maximum efficiency and that both the technical and business aspects of the operation are considered. Current production technology and business skills can be gained by hiring a trained aquaculture technician and by accessing resource and/or educational centers for literature, films, and course work (Appendix B).

The Business Plan

Depending on the size, type, and management level of an operation, an aquaculture farm may be a costly venture. Before beginning the construction of a facility it is essential to determine the set-up and operational costs, as well as to establish methods to obtain the required start-up capital. Introductory literature relating to aquaculture finances is available (Appendix A).

The preparation of a comprehensive business plan and cash flow projection, based on a realistic prediction of fish growth, production capacity, and mortality rate, will enable the farmer to take a good look at the economic feasibility of the proposed operation. The planning process helps identify potential problems, critical areas of strength and weakness, and methods to achieve business goals. If the aquaculture venture appears viable, the business plan can become a valuable tool to assist with the efficient management of the business.

The business plan is a summary of business objectives and how resources will be managed to achieve them. The cash flow is a predictive model, used to illustrate clearly when cash from sales are received and when cash is needed to pay bills as they become due. These documents are required for tax purposes and by lending institutions or investors, as well as providing a planning tool and a control to measure farm success.

When preparing a business plan some of the questions that should be asked are:

- What and where is the market?
- How will capital be raised? What resources are available?
- What materials are needed to construct the pond?
- What are engineering or other consulting fees, if I require assistance?
- How much does feed cost and how much will be needed?
- How many fish and at what cost?
- What about other expenses (electricity, labor, disease treatment etc.)?
- Contingency plans (e.g. in the event of a disease outbreak, or power failure)?
- What is the cost of production?
- What can I expect as a return to investment?

Existing and prospective commercial fish culturists are strongly urged to obtain the following reports and use all available services that will assist in the preparation of business plans and cash flow projections (Appendix B).

- "The preliminary review of markets for existing and potential freshwater aquaculture products" and the

- "Estimated Costs and Returns for Rainbow Trout Production in the Thompson-Okanagan Region" are available to the aquaculturist through the Aquaculture and Commercial Fisheries Branch of the Ministry of Agriculture and Fisheries.

The Farm Management Branch of the British Columbia Ministry of Agriculture and Fisheries can provide the aquaculturist with business counseling, objective reviews of business plans and information on government programs.

Legal Aspects of Freshwater Fish Farming in British Columbia

Wild salmon and trout are of major importance to the sport and commercial fisheries. These fisheries jointly contribute over one billion dollars annually to the economy of British Columbia. The introduction and establishment of new fish species in British Columbia's waters could potentially reduce wild salmonid populations through predation and/or competition for food and habitat. There is also some concern that escaped domestic fish stock may breed with their wild counterparts. Furthermore, the spread of pathogens by transplants of infected fish could have devastating consequences.

The protection and management of the fisheries resource of British Columbia falls under federal and provincial jurisdictions:

- The federal Department of Fisheries and Oceans (DFO) regulates imports/exports of processed fish product and manages marine fisheries including anadromous salmon in fresh water, with the exception of sea-run rainbow trout (steelhead).

- The Ministry of Agriculture and Fisheries (MAF) is responsible for encouraging the growth and orderly development of aquaculture and commercial fishing sectors through extension services and regulation.

- The Ministry of Environment (MOE) is responsible for managing freshwater fisheries (including steelhead), fresh water resources, waste treatment (domestic and industrial) and disposal, wildlife, and the control of pesticide use.

As the lead agency for commercial aquaculture in British Columbia, MAF issues and monitors the commercial aquaculture license and provincial fish processing license. The Aquaculture and Commercial Fisheries Branch also provides technical assistance to marine and freshwater aquaculturists.

Fish species utilized in freshwater aquaculture must be authorized by the Director of the Recreational Fisheries Branch (MOE) and DFO. Transfers of fish into, and within British Columbia are regulated by the Federal/Provincial Transplant Committee.

Farmed fish destined for sale must be processed at processing facilities that are licensed by MAF and registered by DFO. Exemptions to this requirement are operations that prepare fish for direct sale to the consumer from fee-fishing ponds and for direct sale from the farmer to the consumer.

Commercial Aquaculture License

It is unlawful to possess, transport or sell live fish (with the exception of ornamental fish species) unless authorized by a Private Fish Culture Permit or a Commercial Aquaculture License. A Private Fish Culture Permit is issued by the MoE and allows for the holding and raising of fish for hobby or personal use only.

The Commercial Aquaculture License is issued by MAF and allows the holder to rear and sell aquaculture products. All aquaculture facilities operating as a commercial venture in British Columbia require a Commercial Aquaculture License. The license is "site specific" and must be obtained for each site to be developed. The application for the Aquaculture License is accompanied by an Aquaculture Development Plan.

The license application, the Aquaculture Development Plan, and Guide for their completion can be obtained from:

Aquaculture and Commercial Fisheries Branch
Ministry of Agriculture and Fisheries
808 Douglas St.
Victoria, British Columbia
V8W 2Z7

NOTE: The Commercial Aquaculture License must be renewed annually.

Commercial Aquaculture License Fee Schedule:

The fees for initial application, renewals, or amendments are:

Application for initial license	$25
License amendment	$50
License and license renewal for:	
a) facility on private land producing at least $7,500 worth of product	$100
b) facility on private land producing less than $7,500 worth of product	$50
c) facility on Crown Land producing at least $7,500 worth of:	
aquatic plants and fish other than finfish	$150
finfish	$200
d) facility on Crown Land producing less than $7,500 worth of:	
aquatic plants and fish other than finfish	$150
finfish	$200

Permits and Other Requirements for Aquaculture

The permit and license requirements for commercial aquaculture are summarized by Figure 9. The requirements are different depending on the location of the operation (private or Crown land), and the water source (ground water or surface water).

A complete list of contacts and addresses is provided in Appendix B.

Aquaculture License - Explained above.

Business License - Not required if the operation has "farm" status as per the B.C. Assessment Authority. Contact the Municipality within which the operation resides.

Business Plan - Although strongly advised, the preparation of a business plan is optional and necessary only when loans, grants or other outside financing are required. The Ministry of Regional and Economic Development provides free counseling for preparing Business Plans.

Company Registration - An Aquaculture License cannot be issued in a company name unless it is a registered company under the R.S.B.C Companies Act. If the company is not registered the license must be issued in the name of an individual.

Crown Land Investigative Permit, License of Occupation or Lease - Tenure is required to operate on Crown Land. The Ministry of Crown Lands should be contacted for information.

Import Permit - Canadian Fish Health Protection Regulation (CFHPR) enacted under the Fisheries Act (Canada) prohibits the import of live cultured salmonids, eggs of wild or cultured salmonids, and dead products of cultured fish, into Canada or between provinces, unless authorized by an import permit. Permits for the import of live salmonid eggs are issued only if the source facility has been certified as "disease-free". Certified facilities are inspected on a regular basis and declared disease-free as per the CFHPR by a Fish Health Official. Contact DFO for an import permit application.

The intent of these regulations is to prevent the introduction of new fish diseases into Canada and the spread of fish diseases already found in Canada. A number of non-salmonid fishes which are considered to be a risk to native salmonids are prohibited for import.

Processing Farmed Fish - Processing is defined as eviscerating, filleting, icing, canning, freezing, smoking, salting, cooking, pickling, drying, preserving or preparing fish or aquatic plants for market in any other manner. To obtain information on the requirements for processing farmed fish contact the Commercial Fisheries Section, Aquaculture and Commercial Fisheries Branch, MAF.

Sewage Disposal Permit - A Sewage Disposal Permit from either the Ministry of Health, or the Regional District may be required when sewage is discharged on land (For example, to a septic field).

Transplant Committee Approval - Fisheries regulations prohibit the import and within province transport/transplant of live fish unless authorized by license. The Federal/Provincial Transplant Committee is responsible for review of applications to transplant live eggs and fish.

The province has been subdivided into four coastal and five inland zones (Figure 10). Fish transfer within zones takes place with relatively few restrictions. A transfer license ("Form A") to allow transfer within zones is automatically issued with the Commercial Aquaculture License. If the fish to be transferred fail to meet the Conditions of the Form A License then a specific application must be made to the Transplant Committee for a Form B License. Approval may be provisional on a health check of the fish.

Contact MAF for information regarding transplanting live fish.

Waste Management Permit - Discharges of waste into public water bodies, such as a stream or the ocean, may require a permit from the Waste Management Branch of MOE.

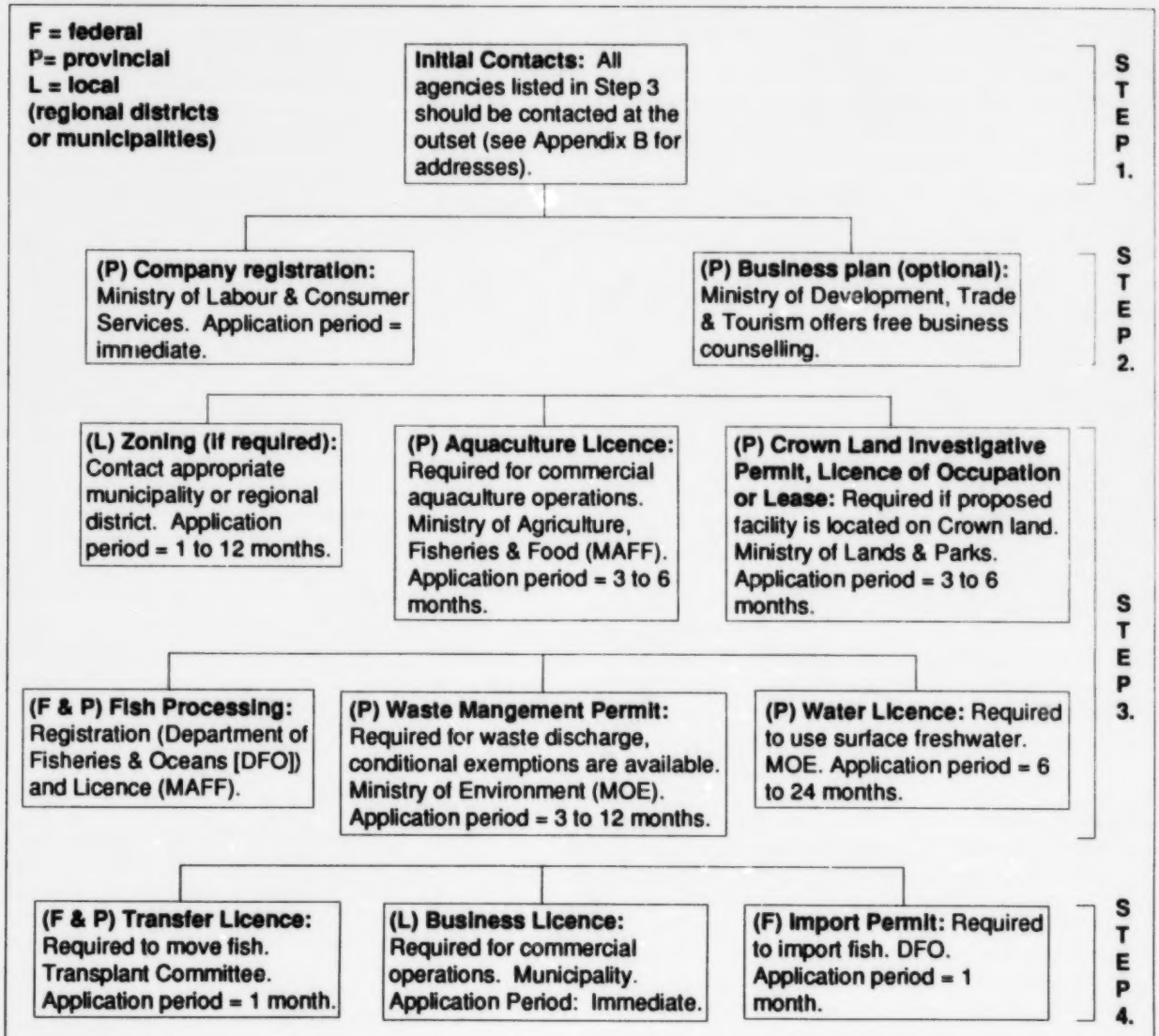

F = federal
P= provincial
L = local
(regional districts or municipalities)
Initial Contacts: All agencies listed in Step 3 should be contacted at the outset (see Appendix B for addresses).
STEP 1.
(P) Company registration: Ministry of Labour & Consumer Services. Application period = immediate.
(P) Business plan (optional): Ministry of Development, Trade & Tourism offers free business counselling.
STEP 2.
(L) Zoning (if required): Contact appropriate municipality or regional district. Application period = 1 to 12 months.
(P) Aquaculture Licence: Required for commercial aquaculture operations. Ministry of Agriculture, Fisheries & Food (MAFF). Application period = 3 to 6 months.
(P) Crown Land Investigative Permit, Licence of Occupation or Lease: Required if proposed facility is located on Crown land. Ministry of Lands & Parks. Application period = 3 to 6 months.
(F & P) Fish Processing: Registration (Department of Fisheries & Oceans [DFO]) and Licence (MAFF).
(P) Waste Mangement Permit: Required for waste discharge, conditional exemptions are available. Ministry of Environment (MOE). Application period = 3 to 12 months.
(P) Water Licence: Required to use surface freshwater. MOE. Application period = 6 to 24 months.
STEP 3.
(F & P) Transfer Licence: Required to move fish. Transplant Committee. Application period = 1 month.
(L) Business Licence: Required for commercial operations. Municipality. Application Period: Immediate.
(F) Import Permit: Required to import fish. DFO. Application period = 1 month.
STEP 4.

Figure 9: Permits and licence structure for a commercial aquaculture venture. (Application period is estimate only)

Water License - A Water License is required to withdraw surface freshwater. The license is issued by Water Management Branch (MOE). Information sheets and application forms are available from Regional Water Managers (MOE).

Information required to obtain a water license includes:

a) a statement of water source and point of diversion;
b) yearly operating period;
c) maximum water quantity required; and
d) water transport method to be used.

Zoning - If the proposed operation falls within the jurisdiction of a municipality or regional district, it must conform to zoning bylaws of the area. Municipal or Regional District offices in the area can provide zoning information.

Figure 10: Salmonid transplant zones, 1991.

Waste Water Management

Potential Environmental Impact

Fish farms and hatcheries normally discharge large volumes of water that contain low levels of waste. Whether or not the cumulative release of these materials can be termed significant, depends upon the concentrations at which they are released and the loading capacity and other characteristics of the receiving water.

Wastes from fish rearing activities may include:

- chemicals and antibiotics employed for the cleaning or the control of diseases, parasites and aquatic weeds;
- bacteria and parasites; and
- excess feed, fish fecal matter, and soluble products such as ammonia produced through fish metabolism.

In most cases, the first two components do not present a problem: antibiotics tend to breakdown rapidly and bacteria/parasites are generally carefully controlled at the farm site. The use of herbicides to control aquatic weeds in ponds could have an effect on your fish stock as well as on downstream water uses. Ministry of Environment (MOE) Regional staff should be contacted prior to their use (Appendix B).

Of most concern are wastes discharged from fish rearing operations, such as; fish fecal matter, residual food and metabolic products. The components of these wastes most commonly identified as pontential pollutants are:

- phosphorus
- nitrogen-containing compounds
- suspended solids
- organics

To best understand how these factors may contribute to the degradation of water quality, one needs to distinquish between dissolved and solid fractions. Two general types of waste are produced by fish: solid material, referred to as settleable and suspended solids; and soluble substances. Solid material may include feces, uneaten feed, other organic matter, and nitrogen- and phosphorus-containing compounds (see figure 4). Decomposition of these materials by heterotrophs (bacteria, fungi) removes oxygen from the water and causes the release of dissolved nutrients (such as phosphorus and ammonia). As a result, the receiving environment may undergo a reduction in dissolved oxygen (D.O.) and an increase in soluble substances. If sludge is left to accumulate, the bottom layers of the sludge will become anaerobic, and toxic gases and compounds can form.

Soluble substances include the dissolved nitrogen and phosphorus that originates from fish metabolism and the breakdown of wastes (ie. solid material). In the soluble form, these nutrients can not be removed by the sedimentation of solids in settling ponds and will be flushed from the system into the receiving environment. Dissolved nutrients enhance growth of aquatic plants and algae and depending on concentration may contribute to reduced water quality. The growth and respiration of plants and algae will cause a reduction in dissolved oxygen. Nitrogen tends to be quickly transported out of the system in soluble form, while phosphorus is more likely to be incorporated into the sediments and slowly released in soluble form.

The natural enrichment of water with nutrients, such as phosphorus and nitrogen, is referred to as eutrophication (Eutrophic = well-nourished). Although in the early stages enrichment can be beneficial (e.g. increased fish production), advanced stages result in excessive aquatic weeds and algal blooms which give an unpleasant taste and odor to the water. Algal blooms will also consume oxygen during the decaying process.

Effluent Quality

The eventual amount of waste discharged from fish culture operations is dependent on facility design, fish management practices, production intensity (kg fish/liter per minute), type of feed, and the waste removal system.

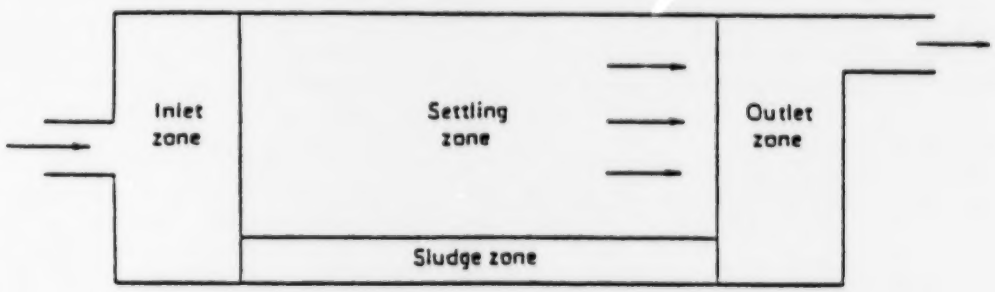
The fish rearing tanks should be designed to be "self-cleaning", thereby enabling the continual removal of most suspended and settleable solids from the tanks by the water flow. Fish will also promote mixing within the water column and further cause the movement of solids out of the rearing tank. Irrespective of the above, some fecal material, unused feed, algae, and other detritus will accumulate in the rearing units. If left for an extended period this material will decompose and (1) remove oxygen from the water, and (2) release soluble nutrients which can not be effectively removed by downstream treatment such as settling. To avoid water quality problems, these solids should be removed from rearing tanks and settling ponds on a regular basis.

The input of fish feed determines the level of wastes generated (refer to Figure 4). The contribution of excess feed to the total waste load can be minimized through good feeding practices (use correct pellet size, avoid over-feeding and remove fines before feeding). Approximately 70% of the feed eaten is passed through the fish as fecal material or soluble metabolic products such as ammonia and phosphorus (ie. 0.7 kg of waste is produced per kg trout). Where possible, it is recommended to use low phosphorus feeds with high digestibility.

Waste Removal

The focus of effluent treatment is to rapidly and efficiently remove settleable solids and suspended solids. The sedimentation of solids in settling ponds is a practical and economical method. A comprehensive description of waste removal systems is beyond the scope of this paper: refer to Appendix A for more complete information.

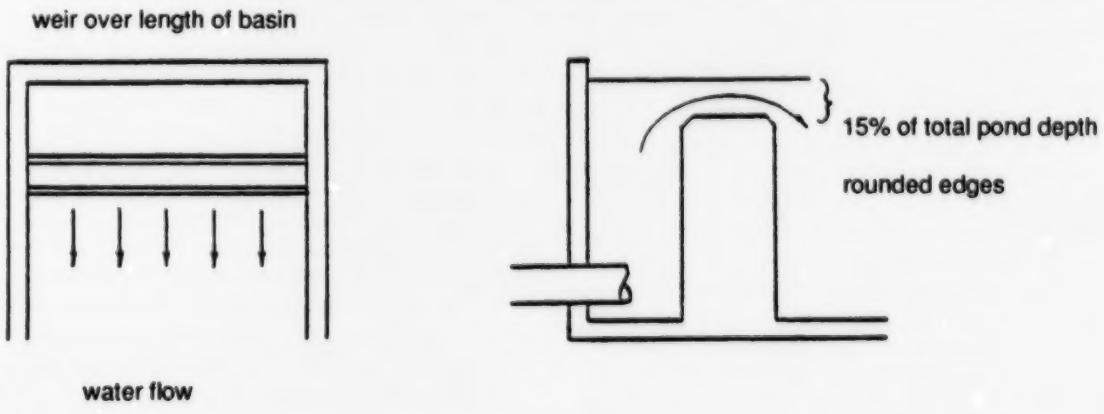
Proper engineering design is essential if sedimentation is to be effective. System design should include four key settling zones, each having a specific purpose. (Source: Stechey & Trudell. 1990. see Appendix A)



Inlet zone: Spread flow over a weir and dissipate energy.
Settling zone: Gravity sedimentation.
Sludge zone: Particles hit bottom, no turbulence, no resuspension
Outlet zone: Water moves over second weir and clarified water is discharged.

The inlet and outlet design is very important to settling performance. The design must consider the characteristics of the settling basin and water flow rates.

Inflow: A point source inflow will create turbulence and/or allow the water to "short-circuit" through the pond to the outflow.



Example of a "good design" (Source: Stechey & Trudell. 1990. see Appendix A).

Outflow: A standpipe outlet is poor for settling, it reduces effective settling area by creating an updraft current which entrains fine solids. Outlet weir should be similar in design to inlet weir.

The accumulated solids should be removed on a regular basis from the settling basin. The liquid sludge can be composted, applied directly to the ground as landfill, or sprayed over agricultural land as fertilizer. MoE regional staff should be contacted for advice on an acceptable disposal procedure.

Education and Extension

Education and training programs designed to address all aspects of aquaculture are available in British Columbia. Simon Fraser University (SFU) offers a Masters degree in Aquaculture that focuses on work experience and includes topics such as, biological sciences, farm management and economics.

The University of British Columbia (UBC) offers graduate and undergraduate programs in aquaculture through the Faculty of Agricultural Sciences. Distance education courses are available from both SFU and UBC.

The University of Victoria, Biology Department, offers cooperative education and undergraduate courses in aquaculture-related studies.

Various colleges throughout the Province offer courses, distance education, and workshops of varying lengths for both existing, as well as prospective, aquaculturists. Formal aquaculture programs are offered by Capilano College, Northwest Community College, North Island College, British Columbia Institute of Technology, and Malaspina College. Contact your local college campus for information on available courses.

For further information on educational programs contact the Colleges and Technical Programs Branch of the Ministry of Advanced Education, Training and Technology, Victoria (Appendix B).

The Ministry of Agriculture and Fisheries provides technical assistance to aquaculturists through numerous extension services. The role of the Aquaculture Industry Development Section of the Commercial Fisheries Branch includes the development of extension materials, coordination of workshops, and collection and distribution of information to the industry.

Appendix A: Additional Reading

The following titles are available through public and university libraries. Addresses are provided for publications that may be difficult to find.

General

Bardach J.E., J.H. Ryther and W.O. McLarney. 1972. Aquaculture: The farming and husbandry of freshwater and marine organisms. Wiley Interscience, New York.

Bryant P., K. Jauncey, and T. Atack. 1980. Backyard fish farming. Prism Press, Sherborne, Dorset.

Hunt M. 1972. Textbook of fish: culture breeding and cultivation of fish. Fishing News Books Ltd. Farnharm, Surrey.

Klontz G.W. 1991. Rainbow trout production on a family-owned farm. Sterling H. Nelson and Sons Inc. Murray Elevators Division. Murray, Utah.

Leitritz E. and R.C. Lewis. 1980. Trout and salmon culture. Publication 4100. Agricultural Sciences Publication, University of California. Berkley, California.

Piper R.G., I.B. McElwain, L.E. Orme, J.P McCraren, L.G. Fowler, J.R. Leonard. 1986. Fish hatchery management. Fish and Wildlife Service, Washington D.C.

Sedgwick S.D. 1985. Trout farming handbook, 4 edition. Fishing News Books Ltd. Surrey, England.

Stevenson J.P. 1980. Trout farming manual. Fishing News Books Ltd. Surrey, England.

Swift D.R. 1985. Aquaculture Training Manual. Fishing News Books Ltd. Surrey, England.

Farm Management and Facility Design

1984. Compendium of low-cost Pacific salmon and steelhead: Trout production facilities and practices in the Pacific Northwest. Prepared for Bonneville Power Administration by Fish Management Consultants. Portland, Oregon.

Barrington R. 1983. Making and managing a trout lake. Fishing News Books Ltd. Surrey, England.

Boyd C.E. 1981. Water quality management for pond fish culture. Elswier Publishing Co. Inc., New York.

Gordon K.G. 1990. Aquaculture Systems: Water Quality Control. Produced by Kevgor Aquasystems. P.O. Box 48851-595 Burrard Street. Vancouver, B.C. V7X 1A8

Sigma Resource Consultants Ltd. 1983. Summary of water quality criteria for salmonid hatcheries. Prepared for Department of Fisheries and Oceans, Vancouver.

Stechey D. and Y. Trudell. 1990. Aquaculture wastewater treatment. Prepared for Ontario Ministry of Environment. Public Information Center Toronto (416) 323-4321.

Carrying Capacities

Klontz G.W. 1990. Carrying capacities in single and multiple-use systems. Salmonid 14(1): 14-18.

Piper R.G. 1972. Managing hatcheries by numbers. Amer. Fisheries and U.S. Trout News. 17(3):10

Environment

1990. Study of freshwater cage culture in Scotland. Prep. for BC Ministry of Agriculture and Fisheries by DPA Group Inc., Vancouver, B.C.

McLarty A.W., A.G. Thachuk, J. Glassco, S. Smith, M. Diffin, J. Gowland, and B. Smyth. 1987. An inventory and environmental evaluation of 23 trout farms in west central Ontario. Proc. Ann. Meet. Aquacult. Assoc. Can. 1:86-87.

Persson G. 1988. Relationships between feed, productivity and pollution in the farming of large rainbow trout. National Swedish Environmental Protection Board, Report 3534. Solna, Sweden.

Fish Health

1984. Fish health protection regulations manual of compliance. Misc. Spec. Publ. 31 (Revised). Department of Fisheries and Oceans, Ottawa.

Herwig N. 1979. Handbook of drugs and chemicals used in the treatment of fish diseases. Charles C. Thomas Publ., U.S.A.

Post G. 1983. Textbook of fish health. T.F.H. Publ. Neptune City, N.J.

Roberts R.J. and C.J. Shepherd. 1986. Handbook of trout and salmon diseases, 2nd edition. Fishing News Books. Surrey, England.

Fish Husbandry and Nutrition

Halver J.E. (ed.). 1972. Fish nutrition. Academic Press Inc., New York.

Hilton J.W. and S.L. Slinger. 1981. Nutrition and feeding of rainbow trout. Canadian Special Publication of Fisheries and Aquatic Sciences # 55.

Munkittrick K.R. Gamete handling techniques to increase reproductive success in cultured rainbow trout. Prep. for Ontario Trout Farmers' Association. International Aquaculture Dev. Co. P.O. Box 434, Erin, Ontario N0B 1T0.

Ross L.G. and B. Ross. 1984. Anaesthetic and sedative techniques for fish. Inst. of Aquaculture, Univ. of Sterling, Sterling, Scotland.

Business, Economic, and Marketing

1990. Preliminary market review for existing and future British Columbia freshwater aquaculture products. Prep. for Ministry of Regional and Economic Development and Ministry of Agriculture and Fisheries by View West Marketing.

1990. Estimated costs and returns for trout production in the Thompson-Okanagan region. Obtain from BCMAF, Victoria.

Allen P.G. 1984. Bioeconomics of aquaculture. Elsevier Science Publishers. Amsterdam.

Ference D. and Associates. 1983. Market for farmed salmonids in British Columbia. Prep. for Marine Resources Branch, B.C. Ministry of Environment.

Gordon K.G. 1990. Produced by Kevgor Aquasystems. P.O. Box 48851-595 Burrard Street. Vancouver, B.C. V7X 1A8

- Financing your Aquaculture Business.
- How to write an Aquaculture Business Plan.
- Marketing your Aquaculture Product.
- Starting an Aquaculture Business.

Miscellaneous Species

Gordon K.G. 1990. How to choose your species. Produced by Kevgor Aquasystems. P.O. Box 48851-595 Burrard Street. Vancouver, B.C. V7X 1A8

1988. Hatchery manual for the white sturgeon, *Acipenser transmontanus*. Publication 3322. Division of Agriculture and Natural Resources, Univ. of California, Oakland, California.

Goldman C.R. (ed.). 1983. Freshwater Crayfish V. Papers from the Fifth International Symposium on Freshwater Crayfish, Davis, California, 1981. AVI Publishing Company, Inc. Westport, Connecticut.

Huner, J.V. and Brown E.E. (ed.). 1985. Crustacean and mollusk aquaculture in the United States. AVI Publishing Company, Inc. Westport, Connecticut.

Stickney R.R. (ed.). 1988. Culture of nonsalmonid freshwater fishes. CRC Press Inc. Boca Raton, Florida.

Periodicals and Journals

Many useful articles may be found in periodicals and journals. The following list provides names of several journals that may prove useful to the aquaculturist and can be found in the library.

Aquaculture Association of Canada Bulletin
Aquaculture Association of Canada
PO Box 1987, St. Andrews NB
E0G 2X0

Aquaculture Magazine
P.O. Box 2329. Asheville, North Carolina
USA 28802

Northern Aquaculture
4611 William Head Road. Victoria, B.C.
V8X 3W9

Fish Farmer
Subscription Department
205 East 42nd Street. New York, New York
USA 10017

Fish Farming International
Subscription Department
Canada House, Kildare Close. Ruislip,
Middlesex United Kingdom HA4 9XB

Fish Farm News
4111 Sailor Street
Campbell River, B.C.
V9W 3S4

Progressive Fish-Culturist
American Fisheries Society
5410 Grosvenor Lane, Suite 110. Bethesda,
Maryland USA 20814

Appendix B: Contacts and Addresses

Government

Lead Agency for Aquaculture & Commercial Aquaculture Licence

Ministry of Agriculture, Fisheries and Food
Aquaculture and Commercial Fisheries Branch
808 Douglas Street
Victoria, B.C.
V8W 2Z7 Telephone: 387-1166

Aquatic Land Lease/Licence

Ministry of Lands and Parks
Land Policy Branch
4000 Seymour Place
Victoria, B.C.
V8V 1X4 Telephone: 387-1800

Regional Offices:

Cariboo Region (Williams Lake)	398-4250
Kootenay Region (Cranbrook)	426-1414
Lower Mainland Region (Burnaby)	660-5500
Omineca Region (Prince George)	565-6245
Peace Region (Fort St. John)	787-3411
Skeena Region (Smithers)	847-7334
Thompson-Okanagan Region (Kamloops)	554-3144
Vancouver Island Region (Victoria)	387-5011

Business Registration

Ministry of Finance and Corporate Relations
Registrar of Companies
940 Blanshard Street
Victoria, B.C.
V8W 3E6 Telephone: 387-4471

Education

Ministry of Advanced Education, Training and Technology
Colleges and Technical Programs Branch
818 Broughton Street
Victoria, B.C.
V8W 1E4 Telephone 387-1940

Financial Assistance Programs/Business Counselling

Ministry of Agriculture, Fisheries and Food
Agricultural Finance Branch
808 Douglas Street
Victoria, B.C.
V8W 2Z7 Telephone: 356-5121

B.C. Trade Development Corporation
760 Pacific Boulevard South
Vancouver, B.C.
V6B 5E6 Telephone: 660-3900

Call toll free from the anywhere in the Province of British Columbia for business information: 1-800-972-2255.

Private Fish Culture Permit

Ministry of Environment
Recreational Fisheries Branch
780 Blanchard Street
Victoria, B.C.
V8W 1X5 Telephone: 387-4573

Regional Offices:

Kootenay Region (Nelson)	354-6333
Lower Mainland Region (Surrey)	584-8822
Northern Region (Prince George)	565-6145
Northern Sub-Region (Smithers)	847-7303
Southern Interior Region (Kamloops)	374-9717
South/Inter. Sub-Region (Penticton)	493-8261
South/Inter. Sub-Region (Williams Lake)	398-4211
Vancouver Island Region (Nanaimo)	584-8822

Information on Fish Processing Regulations

Federal Inspection and Registration:
Inspection and Special Services Branch
Department of Fisheries and Oceans
2250 South Boundary Road
Burnaby, B.C.
V5M 4L9 Telephone: 666-7952

Provincial Licence:
Commercial Fisheries Section
Aquaculture and Commercial Fisheries Branch
Ministry of Agriculture, Fisheries and Food
808 Douglas Street
Victoria, B.C.
V8W 2Z7 Telephone: 387-9567

Sales Tax Exemption/Bona Fide Aquaculturist Certificate

Ministry of Finance and Corporate Relations
Consumer Taxation Branch
1061 Fort Street
Victoria, B.C.
V8V 3K5 Telephone: 387-0656

Ministry of Agriculture, Fisheries and Food
Aquaculture & Commercial Fisheries Branch
808 Douglas Street
Victoria, B.C.
V8W 2Z7 Telephone: 356-1604

Transplant Committee
Ministry of Environment
Recreational Fisheries Branch
780 Blanshard Street
Victoria, B.C.
V8V 1X5 Telephone: 387-4573

Waste Management Permit
Ministry of Environment
Waste Management Branch
810 Blanshard Street
Victoria, B.C.
V8V 1X5 Telephone: 387-9966
Alternate contacts are regional MoE offices listed above.

Water Licence
Ministry of Environment
Water Management Branch
765 Broughton Street
Victoria, B.C.
V8V 1X5 Telephone: 387-5981
Alternate contacts are regional MoE offices listed above.

Freshwater Aquaculture Organizations

British Columbia Trout Farmers Association
c/o Mr. Al Ludwig
RR#3, 7272 - 252A Crescent
Aldergrove, B.C.
V0X 1A0 Telephone: 856-4456

British Columbia Freshwater Aquaculture Cooperative
c/o Rob Hutton
Shuswap Nation Tribal Council
345 Yellowhead Hwy. Kamloops, B.C.
V2H 1H1 Telephone: 374-9345

Kootenay Trout Growers Association
Box 127
Salmo, B.C. Telephone: 357-2166

Other Aquaculture Organizations

Aquaculture Association of B.C.
RR#3, 1299 Maple Road
Sidney, B.C.
V8L 3X9 Telephone: 655-3117
President: Lorne Clayton

British Columbia Salmon Farmers Association
#1010 - 1030 West Pender Street
Vancouver, B.C.
V6E 4A4
Tel: 682-3077 Fax: 669-6974
President: Mr. Denis Martell

Sunshine Coast Aquaculture Association
P.O. Box 2360, Sechelt, B.C.
V0N 3A0 Telephone: 885-3619
President: Mr. Kevin Onclin

Campbell River Aquaculture Association
550 Charles Place, Campbell River, B.C.
V9W 3Y2 Telephone: 286-1011
President: Mr. Paul Tate

Assoc. of Aquaculture Veterinarians
(B.C. Veterinary Medical Association)
155 - 1200 West 73rd Ave., Vancouver, B.C.
V6P 6G5 Telephone: 266-3441
President: Dr. Kim Klotins

B.C. Aquaculture R & D Council
1010 - 1030 West Pender Street, Vancouver, B.C.
V6E 4A4 Telephone: 683-3387
Executive Director: Mr. John Spence

Canadian Aquaculture Producers' Council
c/o B.C. Salmon Farmers' Assoc. (see above)
President: Al Archibald

Canadian Aquaculture Association
P.O. Box 1987, St. Andrew, New Brunswick
E0G 2X0 Telephone: (506) 529-8854
President: Ms. Deborah Turnbull

Canadian Aquaculture Suppliers Assoc.
Box 5255, Main Post Office, Vancouver, B.C.
V6B 4B5 Telephone: 731-1454
President: Mr. Alan Ismond

Appendix C: A Checklist for the Prospective Fish Farmer

Legal Aspects

The appropriate government agencies should be contacted to obtain required licenses and permits (Appendix B). Contact the MAF for information on federal and provincial regulations that will affect your operations.

For example:

- aquaculture license;
- regulations governing the importation of eggs and
  - the movement of fish and eggs within the province;
- use of algicides, chemicals and antibiotics;
- water rights, water access and water discharge; and
- fish processing.

Physical Features of Production Site

Site Location:

- Natural elevations of selected site should allow for complete drainage of ponds.
- Soils should be analyzed to ensure their physical and chemical properties are suitable for water retention and fish culture.
- Aerial spraying for insects and weeds should not occur on adjacent lands and soil should not contain toxic residues.
- Site should not be subject to flooding.
- The proximity to a suitable market, supply services, labor pool, and processor are important factors in site selection.

Water Supply:

- The water quality should be tested with respect to its capability to support fish culture.
- The quantity of water available and the water license should meet existing and future needs.
- Be aware of advantages and disadvantages of the proposed water source. Can the water be accessed cost efficiently, and is an alternative source available in case of emergency?
- How does the temperature and dissolved oxygen of the water supply vary throughout the year?
- Provisions should be made to aerate water if required.
- If surface water is used the stock should be protected from predators and the introduction of wild fish species.

Fish Source

- Are fish to be produced on site or purchased from other fish breeders?
- Reliable sources of good quality, disease-free fingerlings or fish should be identified.

Farm Management

- The following should be available on farm site:
  - experienced aquaculturist and/or skilled help;
  - equipment for water quality testing and disease diagnosis;
  - emergency power back-up;
  - all-weather access to all facilities; and
  - area for expansion.
- Facility design should provide as much efficiency as possible in day-to-day activities.
- Record sheets should be developed to record details associated with water supply, fish mortality, feed, fish, disease, and other costs.

Feeding

- A reliable source of high quality feed should be available on demand throughout the growing season.
- Feeding schedules (based on water temperature and fish weight) should be developed and followed. To ensure maximum feed consumption and growth, the farmer should be familiar with the following:
  - calculation of daily feed rates and feed conversion rates,
  - pellet sizes best suited for size of stock,
  - floating or sinking feed, and
  - methods of feeding (by hand, automatic feeders, or demand feeders).
- Fines should be removed from feed prior to distributing feed.
- During feeding the farmer should watch the behavior of his stock, changes could indicate a potential problem.

Harvesting and Processing

- What is the most economical, labor efficient method of harvesting the fish? Facilities should be designed to allow for easy access to the fish.
- Holding facilities for market-sized fish may be required.
- Special equipment needs for handling fish from harvesting to processing should be assessed.
- Are the fish to be processed on site? If so, BCMAF should be contacted to discuss federal and provincial requirements for setting up a processing facility. If not, contact a freshwater aquaculture organization (Appendix B) for a list of fish processors in your area.
- It may prove more cost-efficient to contract a local processor to handle your annual production.
- The maintenance of high quality product is a major consideration during harvest and processing.

Business of Trout Farming

Economics:

A business plan should be developed that details the cost of land and capital expenditures for fish stock, buildings, pond construction; operating capital for labor, financing, production, harvesting, marketing, and insurance; the plan should also contain depreciation schedules and a profit and loss estimate.

Markets:

- Contact a freshwater aquaculture organization for information on existing and alternative processing and marketing strategies.
- Market outlets should be studied with respect to:
- Market demand as to quantity, price, and product form. Be prepared to provide a reliable source of high quality product, in the requested types, form and quantity. Backup?; and
- Volume and timing of production should be market-driven.
- Methods for efficient distribution of product should be in place.
- A budget for market promotion should be incorporated into the business plan.

Appendix D: Estimation of Water Flow

Direct Measurement

Collect the water into a container that has been marker at a given volume and determine the time required to fill the container to the mark.

For example:
A 15 gallon pail is marked at 10 gallons, the pail is filled to the mark in 2.5 seconds.

Therefore the available water flow at that point in time is:

$$\frac{\text{10 gallons}}{\text{2.5 seconds}} \times 60 \text{ seconds} = 240 \text{ gallons per minute}$$

Measurement of Flow in Streams

A crude estimate of water flow may be made for larger streams by using the following formula:

$$\text{Flow} = \frac{D \times W \times L \times A \times 60 \text{ seconds}}{T}$$

- Select a section of the stream where the water runs relatively smoothly over an area of fairly constant width and depth. The section should be as long as practically possible. Measure length of section (L).
- Determine the average water depth (D).
- Determine the average stream width (W).
- Place an orange in the water at the top of the section and measure the time (seconds) taken to move to the bottom of the area. Calculate an average time (T = seconds) by repeating this procedure four or five times.
- (A) is a factor that accounts for differences in rate of water flow over smooth and rough surfaces. A = 0.9 for smooth sand etc., whereas A = 0.8 for rough rocks etc.

Use of Weirs to Measure Flow *(Source: Fish Hatchery Management. 1986. Piper et al.)*

The discharge of water through a rearing channel can be easily measured if a rectangular weir (Figure D-1) is built into the channel. The water head behind the weir must be measured. Reference of this head to a calibration chart (Table D-1) gives the corresponding discharge in gallons per minute.

The following considerations must be met if water flow determinations are to be accurate:

- The head should never be measured closer to the weir than 2.5 times the depth of water flowing over the weir crest. A practical measuring technique is to drive a stake into the channel bottom so that its top is exactly level with the weir crest. The head is the depth of water over the stake which can be measured with a thin ruler. If a wall has been constructed behind the weir, the ruler can be mounted permanently for easy reference.
- The weir crest must be level and the weir faces exactly vertical.
- The weir crest, formed with a metal plate, must be leak-proof, sharp or square-edged, and no thicker than 1/8 inch
- The channel above the weir must be straight, level and clean to ensure smooth water flow.

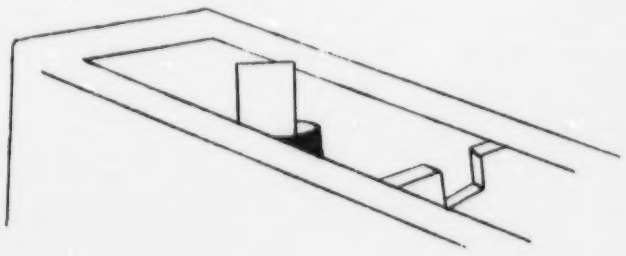


Figure D-1. Rectangular weir in concrete raceway.

HEAD (INCHES)	DISCHARGE (GALLONS PER MINUTE)	HEAD (INCHES)	DISCHARGE (GALLONS PER MINUTE)	HEAD (INCHES)	DISCHARGE (GALLONS PER MINUTE)
0.250	5.00	4.25	317	8.25	860
0.500	14.0	4.50	346	8.50	900
0.750	23.0	4.75	375	8.75	939
1.00	36.0	5.00	405	9.00	978
1.25	50.0	5.25	436	9.25	1,020
1.50	66.0	5.50	468	9.50	1,060
1.75	84.0	5.75	500	9.75	1,100
2.00	102	6.00	533	10.0	1,150
2.25	122	6.25	567	10.3	1,190
2.50	143	6.50	601	10.5	1,230
2.75	165	6.75	636	10.8	1,280
3.00	188	7.00	672	11.0	1,320
3.25	212	7.25	708	11.3	1,370
3.50	237	7.50	745	11.5	1,410
3.75	263	7.75	783	11.8	1,460
4.00	290	8.00	820	12.0	1,510

Table D-1. Relation between head and water flow (gpm) for rectangular weirs. The discharge values assume a 1-foot-wide weir crest; for crests with a wider or shorter crest, multiply the given values by the actual width in feet (Source: Fish Hatchery Management. 1986. Piper et al.).

Appendix E: Recordkeeping

Efficient recordkeeping is an integral part of all business plans and is the cornerstone to the success of any business. The farmer can use production records to measure and balance the inputs and outputs, evaluate operating efficiencies, anticipate problems with fish stock, and to plan future activities.

The factors listed below should be considered when designing record sheets for daily, monthly and annual accounts (Piper et al. 1986). Although production records should be simple and quick to complete, they must contain enough information to provide answers to the following questions:

Water:

- Temperature
- Water quality information
- Water flow rate into each unit and total flow through the facility
- Volume (cubic feet) for each rearing unit and the entire farm
- Exchange rate for each unit and for total farm

Fish:

- Weight and number of fish and eggs at the beginning and end of record period
- Mortality
  - Number of mortalities (fish or eggs) actually recovered
  - Unaccountable losses determined by comparison of inventories
- Percent monthly and annual mortalities
- Fish and eggs shipped and received
- Gain in weight per fish and total farm biomass
- Date eggs were taken, number per given volume, and source
- Date of first feeding of fry
- Number per pound or kilogram of all lots of fish
- Data on broodstock

Feed:

- Composition
- Cost per pound (kilogram) of feed
- Amount of feed fed as a percentage of fish body weight
- Weight of feed fed per weight of fish produced (FCR)
- Cost per pound (kilogram) of fish gained

Disease:

- Occurrence, type and possible contributing factors
- Type of control and results

Appendix F: English-Metric Conversions

English		Metric
Length		
1 inch	=	2.54 centimeters
0.39 inch	=	1 centimeter
1 foot (12 inches)	=	30.5 centimeters (.31 meters)
3.28 feet	=	1 meter
Area		
1 square inch	=	6.45 square centimeters
0.15 square inch	=	1 square centimeter
1 acre (4,840 sq. yards)	=	0.40 hectares
2.47 acres	=	1 hectare(10,000 sq. meter)
Volume		
1 gallon	=	3.79 liters
0.26 gallons	=	1 liter
1 ounce	=	29.57 milliliters
1 acre-foot (or 325,851 gallons or 43,560 cubic ft.)	=	1,233.6 cubic meters
Weight		
1 pound	=	0.45 kilograms
2.2 pounds	=	1 kilogram
1 English ton (2,000 lbs)	=	0.91 metric ton
1.10 English tons	=	1 metric ton (1,000 kg)
Flow Rate		
1 cubic foot/second	=	28.32 liters/second
0.35 cubic foot/second	=	1 liter/second
1 cubic foot/minute	=	28.32 liters/minute
0.35 cubic foot/minute	=	1 liter/minute
1 gallon/minute	=	3.785 liters/minute
0.264 gallons/minute	=	1 liter/minute
Concentration		
1 milligrams/liter	=	1 part per million
3.79 milligrams/gallon	=	1 part per million